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Thermoelectric Properties of Sputtered Iron-Silicide

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for applying them to thermoelectric devices. The highest Seebeck coefficient of 17.84 μV/K are obtained. It is the first attempt to investigate thermoelectric properties of oxygen-included iron-silicide films.

Keywords: Iron-silicide; Thermoelectric; Facing target sputter

1. Introduction

Iron disilicide, β-$FeSi_2$, is one of ecologically friendly semiconductors, which has attracted much attention as a promising material for optoelectronic applications, such as light emitted diodes and infrared sensors [1]. This is also expected as a high efficiency thermoelectric material because of its Seebeck coefficient (0.2-0.6 mVK^{-1} at 600 K) [2]. We have prepared iron-silicide thin films for coating and solar cell applications by a facing target (FT) sputtering method. We have found that the films have the nano-indentation hardness of 10 GPa [3]. In addition to this we have found that Fe-Si films including oxygen prepared by the FT sputter have larger absorption edges, compared with β-$FeSi_2$. The absorption edges shift to higher photon energy side as the oxygen content in the film increases. A detail of oxygen included iron disilicide will be reported in the separate paper [4]. FT sputtering equipments consist of two targets positioned in parallel and the substrate places in the direction perpendicular to the two targets outside of the plasma formed between them. Compared with conventional sputtering equipments, in which a target and a substrate face each other, this method is characterized by higher plasma density, less film damage by plasma and less rise in substrate temperature [5]. In this study, we aim at fabrication of thermoelectric

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devices by using the sputtered and oxygen included iron-silicide thin films. We here report on the thermoelectric properties of the oxygen included iron-silicide thin films prepared by the facing target sputtering.

2. Experiments

Oxygen-included thin $FeSi_2$ films were deposited by the FT dc sputtering with the base pressure of 10^{-4} Pa on glass or silica glass substrates. Fe-Si alloy targets with a purity of 3 N (Kojyundo Chemical Laboratory) were sputtered at Ar pressure of 0.5 Pa and room temperature. Two samples, labeled 1 and 2, were prepared at the dc power and deposition time of 0.2 and 50 min, and 0.6 kW and 1350 min, respectively. Indium (sample 1) or Al (sample 2) were deposited as a electrode. The films were found to be amorphous because no XRD peaks were obtained.

The thermoelectric power of the thin films were measured while imposing a temperature difference ΔT between hot and cold junctions of the films. The both ends of the samples were contacted with a heater and a heat sink through sample folders made of cupper blocks. The imposed temperature gradient was parallel to the length of the thin films and ranging from 300 K to 500 K. Temperatures were measured by thermocouples (chromel–alumel) attached to the sample folders near the hot and cold junctions.

3. Results and Discussion

Figures 1 and 2 show the thermoelectric power as a function of temperature differences for the sample 1 and 2, respectively. These samples were n-type because the higher temperature electrode had positive thermoelectric power. This agrees with Hall measurement results [6]. The Seebeck coefficient for the sample 1 was 1.51 μV/K. Temperature region for sample 2 seems to be divided by three parts, namely blow 200 K, 200 K to 400 K and above 400K. The Seebeck coefficients for each region were 1.78, 3.27 and 17.84 μV/K, respectively. As decreasing the dc power, we have obtained higher Seebeck coefficient.

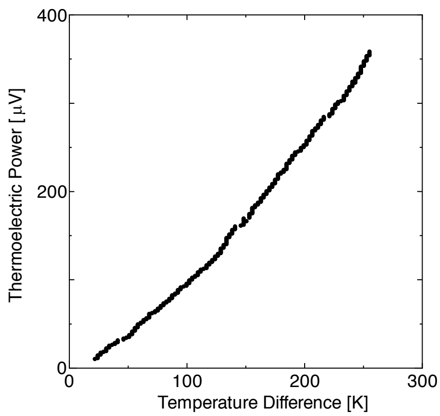

Fig. 1 Thermoelectric Power of sample 1.

The Seebeck coefficient for n-type nondegenerate semiconductors is given by

$$\alpha = -\frac{k}{e}\left(\frac{3}{2} + \frac{E_C - E_F}{kT}\right)$$

where α is Seebeck coefficient, k Boltzmann constant, e magnitude of electronic charge, E_C bottom of conduction band and E_F Fermi level [7]. When E_C-E_F=0, the lowest Seebeck coefficient value of 1.29×10^{-4} V/K can be calculated. The obtained Seebeck coefficient in this study is lower than this, indicating that the samples are degenerate. This agrees with the Hall measurement result that the carrier density is 10^{20} cm^{-3} orders of magnitude [6].

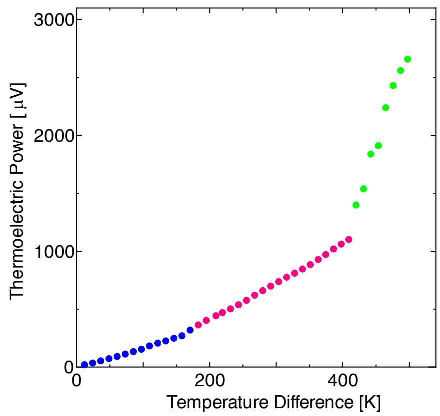

Fig. 2 Thermoelectric Power of sample 2.

4. Conclusion

The thermoelectric properties are investigated for oxygen included iron silicide thin films prepared by FT dc sputtering. The highest Seebeck coefficient of 17.84 μV/K is obtained. This value is lower than that for bulk $FeSi_2$ thermoelectric devices. It is, therefore, needed to improve thermoelectric properties. For this we intend to optimize preparation conditions, such as deposition power and pressure. From the Hall measurement the films are found to be degenerate. We suppose this degeneracy comes from oxygen-incorporation. However, effects of oxygen-incorporation on thermoelectric properties of the films are not clear because of lack of data. Then we need further investigation, such as temperature dependence of electrical porperties.

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